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Abstract: Background: Recent studies in anaesthesia and intensive care indicate that a team's ability to adapt its coordination activities to changing situational demands is crucial for effective teamwork and thus, safe patient care. This study addresses the relationship between adaptation of team coordination and markers of clinical performance in response to a critical event, particularly regarding which types of coordination activities are used and which team member engages in those coordination activities. **Methods:** Video recordings of 15 two-person anaesthesia teams (anaesthesia trainee plus anaesthesia nurse) performing a simulated induction of general anaesthesia were coded, using a structured observation system for coordination activities. The simulation involved a critical event—*asystole* during laryngoscopy. Clinical performance was assessed using two separate reaction times related to the critical event. **Results:** Analyses of variance revealed a significant effect of the critical event on team coordination: after the occurrence of the *asystole*, team members adapted their coordination activities by spending more time on information management—a specific type of coordination activity ($F_{1,28}=15.17$, $P=0.001$). No significant effect was found for task management. The increase in information management was related to faster decisions regarding how to respond to the critical event, but only for trainees and not for nurses. **Conclusions:** Our findings support the claim that adaptation of coordination activities is related to improved team performance in healthcare. Moreover, adaptation and its relationship to team performance were found to vary with regard to type of coordination activities and team member.

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CLINICAL PRACTICE

Adaptation in anaesthesia team coordination in response to a simulated critical event and its relationship to clinical performance

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Editor's key points

- Adaptation of team coordination was studied during a simulated critical incident.
- Video recordings and structured observations and two different reaction times to the incident were studied.
- Teams adapted to the critical event, significant effect being on information management leading to faster decision-making.
- The study supports the claim that team adaptation is important in improving performance during critical events.

Background. Recent studies in anaesthesia and intensive care indicate that a team's ability to adapt its coordination activities to changing situational demands is crucial for effective teamwork and thus, safe patient care. This study addresses the relationship between adaptation of team coordination and markers of clinical performance in response to a critical event, particularly regarding which types of coordination activities are used and which team member engages in those coordination activities.

Methods. Video recordings of 15 two-person anaesthesia teams (anaesthesia trainee plus anaesthesia nurse) performing a simulated induction of general anaesthesia were coded, using a structured observation system for coordination activities. The simulation involved a critical event—*asystole* during laryngoscopy. Clinical performance was assessed using two separate reaction times related to the critical event.

Results. Analyses of variance revealed a significant effect of the critical event on team coordination: after the occurrence of the *asystole*, team members adapted their coordination activities by spending more time on information management—a specific type of coordination activity ($F_{1,28}=15.17$, $P=0.001$). No significant effect was found for task management. The increase in information management was related to faster decisions regarding how to respond to the critical event, but only for trainees and not for nurses.

Conclusions. Our findings support the claim that adaptation of coordination activities is related to improved team performance in healthcare. Moreover, adaptation and its relationship to team performance were found to vary with regard to type of coordination activities and team member.

Keywords: adaptation; clinical performance; coordination; critical event; teamwork

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Increasing complexity in healthcare has led to a growing inter-dependence of tasks and functions which has, in turn, created a need for increased cooperation and team-based forms of work organization. This is particularly true in dynamic domains of healthcare such as anaesthesia, surgery, and intensive care where effective teamwork has been shown to be important for safe patient care.^{1–2} Research on patient safety in anaesthesia^{3–4} has underlined the significance of team-processes such as communication and coordination.^{5–6} Similarly, studies from other dynamic domains of healthcare—intensive care and surgery—support the claim that teamwork is important for safe patient care.^{7–8}

Coordination is a central feature of teamwork.⁹ This is particularly true in the operating theatre where effective team coordination is a vital component since one's actions can immediately require another team member to react appropriately.¹ Within the scope of medical teams, we regard coordination as those activities that aim at *organizing the joint patient treatment*—in contrast to the patient treatment itself. Additionally, we consider coordination a *process* comprising specific *observable behaviours*, which include information exchange (e.g. asking a question) and mutual adjustment of actions (e.g. distributing tasks among team members).¹⁰ The ability of a team to adapt its coordination

activities to changing situational demands (e.g. raising task-load, occurrence of a critical event) has been identified as a major characteristic of successful teams.^{11–12} Adaptive coordination is especially relevant in anaesthesia where levels of workload, action density, and standardization vary considerably.^{13–15} Moreover, the inherent dynamics of anaesthetic practice constantly bear the possibility of potentially critical, non-routine events.⁴

Studies on team coordination in healthcare highlight three performance critical factors. In anaesthesia, for example, higher performing teams were found to increase their task management—a specific *type of coordination activity* corresponding to the mutual adjustment of actions—in response to the occurrence of non-routine events.¹⁶ Appropriate *timing* (e.g. when to share information) is also related to successful patient treatment.^{17–18} Other studies point to the importance of considering *inter-professional differences* as team members contribute differently to team coordination depending on their role and professional background.^{19–20} Although all three factors have been found to affect coordination activities, most studies focus on a single aspect.

The current work represents a first attempt to integrate these factors. This study aims to investigate how anaesthesia teams adapt their coordination activities in response to a simulated critical, non-routine event—asystole during laryngoscopy. After previous research on team coordination in healthcare, we hypothesize that anaesthesia teams will adapt their coordination activities in response to a critical event. Specifically, we expect differences in adaptation activities to include (i) the type of coordination activities and (ii) the team member. Additionally, we expect (iii) the degree of adaptation to be related to clinical performance—that is, higher performing teams being more adaptive to the critical event.

Methods

The study was approved by the local ethics committee (KEK-StV-Nr. 09/05) and registered at ClinicalTrials.gov (NCT00706108). We obtained written consent from all participants before the simulation.

Participants were 15 anaesthesia trainees and 15 anaesthesia nurses from a large teaching hospital working in teams of two. As all were volunteers, they represented a convenience sample. Participants were only included if they had at least 3 months clinical experience within the department to assure sufficient familiarity with the anaesthesia equipment and procedures. [Please note that some of the video recordings (i.e. the raw data) were used in a previous study focusing on a different process (leadership) and also using another observation system and other markers of performance.³⁰]

A simulator mannequin for advanced life support (Laerdal© mannequin allowing mask ventilation, intubation and rhythm simulation using Megacode© heart rhythm simulator) was used. To increase ecological validity, we conducted the simulation in a genuine operating theatre. The hospital's

standard anaesthesia equipment including drugs, needles, stethoscope, and the usual airway devices was provided. Participants were videotaped during the entire scenario. Data were also recorded from the vital signs monitor and the ventilator which were synchronized with the videotapes by a master–slave recording system, to assure simultaneity.

The scenario was a standard anaesthesia induction. The patient represented an ASA I male with a very short clinical record; he was undergoing excision of a pilonidal sinus, in the prone position under general anaesthesia with tracheal intubation. The most common anaesthesia team composition for this type of procedure includes an anaesthesia trainee with sufficient practical experience and an anaesthesia nurse or nurse student. In the scenario, a staff anaesthetist was available if required. When designing the scenario, we aimed at securing a high level of standardization, minimizing the influence of extraneous variables on team coordination (e.g. variance in patient status or team composition).

During laryngoscopy, asystole was simulated as a critical event. Sinus rhythm returned when predefined actions consistent with ACLS guidelines were taken.²¹ The simulation was always conducted by the same two operators (staff anaesthetist and research fellow).

Measures

Coding of team coordination

Team coordination was operationalized as all team-member activities aimed at organizing the joint task execution (e.g. delegating a task, requesting information). We coded these activities with an established observation system for anaesthesia teams consisting of 33 mutually exclusive codes which are grouped into five main categories: 'information management', 'task management', 'coordination via work environment', 'meta-coordination', and 'other communication'.^{12–16–19} In this study, we focused on 'information management' and 'task management'. See Supplementary Appendix for a full description of these categories, including the respective codes and examples of behaviours.

We classified each coordination activity according to its code (e.g. information request), its timing (i.e. beginning, end, and duration), and the team member (e.g. anaesthesia nurse). Coding was performed by a trained organizational psychologist on a standard PC using Interact©—a specialized software for behavioural observation (Mangold International GmbH, Arnstorf, Germany).

Clinical performance

An experienced staff anaesthetist blinded to our hypotheses assessed various reaction times related to the successful treatment of the asystole using the synchronized video, monitor, and ventilator data. We calculated two distinct markers of performance based on these measures. 'Decision latency' was defined as the period from the point in time when the team recognized the asystole until they decided how to respond to it. 'Execution latency' was defined as the period from deciding what to do until counteractions

were successfully taken—that is, until restoration of sinus rhythm. We decided to use these measures because ‘time to detect’ and ‘time to solve a problem’ are common markers of performance in anaesthetic simulations.²² Moreover, they represent an essential aspect of clinical performance in a resuscitation situation where a timely response is vital. Both markers were measured in seconds; therefore, high values indicate low performance.

Data handling

Since we were mainly interested in team coordination in relation to the critical event, we restricted our analysis to the time from the announcement to intubate the patient until restoration of sinus rhythm. Relevant task characteristics were kept constant, both within and between cases, enabling us to isolate the effect of the critical event. In order to assess effects of timing, we divided this period into two phases with onset of the asystole as the discriminating event. In the following section, we will refer to the first phase which extended from the announcement to intubate to the asystole as routine (Phase I). The second phase, from the asystole until the sinus rhythm was re-established, is the critical event (Phase II).

Our analyses focused on *information management* (i.e. the coordination of information relevant for task execution) and *task management* (i.e. coordination of actions or tasks), since previous studies have indicated that these categories represented the two most frequent and performance-relevant types of coordination activities.^{12 16} For each phase (routine and critical event), we calculated separate task management and information management measures for both team members. Individual measures were defined as the time spent on the respective coordination category in relation to phase duration. For example, if an anaesthesia nurse spent 2 min of a 4 min phase on task management, his/her task-management score for this phase was 50%. Since percentages are nominal data, we used arcsine transformation as used in similar studies.¹⁸ To obtain a measure of adaptation—changes in coordination activities in response to the critical event—we calculated the difference between phases I and II. By using differences rather than absolute values, we also controlled for the baseline of coordination activities of each team.¹⁶

Statistical analysis

Separate analyses for task management and information management were conducted on the arcsin-transformed data [in the respective table and figure (see below), however, we used untransformed percentages for ease of illustration]. A 2×2 analysis of variance (ANOVA) were conducted with phase (routine and critical event) as a within-subject factor and team member (Trainee, Nurse) as a between-subject factor to test whether anaesthesia teams adapted their coordination activities to the critical event and whether this adaptation was influenced by (i) the type of coordination activities and (ii) the team member. Differences in coordination activities between the two phases with the two performance measures—decision latency and execution latency—were correlated to test whether the degree of adaptation in coordination activities was related to the clinical performance of the teams. All analyses were performed with IBM SPSS Statistics Version 17 (SPSS, which was acquired by IBM in November 2009).

Two of the 15 videos were randomly selected for coding by a second trained organizational psychologist. Inter-coder reliability was subsequently calculated using Cohen's κ coefficient.²³ We allowed for a lag of 2 s for start and end times for second-by-second coding.²⁴ The analyses revealed good reliability scores for information management and task management of 0.84 and 0.72, respectively; comparable values were obtained in a previous study.¹²

We applied a similar procedure to assess the reliability of the markers of performance. A second experienced staff anaesthetist blinded to our hypotheses determined the reaction times for three randomly selected cases. An intra-class correlation coefficient (ICC) analysis revealed an ICC of 0.96, indicating high reliability.²⁵

Results

Six of the participating anaesthesia trainees were female (40%); eight of the anaesthesia nurses were female (53%). Six of the anaesthesia trainees (40%) reported having <6 months experience, three had between 6 and 18 months (20%), two had between 18 and 36 months, and four reported having more than 36 months experience as an anaesthesia trainee. According to our coding scheme, participants spent an average of 35.22% of their time on coordination activities (Table 1).

Table 1 Amount of time team members spent on coordination activities as percentages of the respective phase duration. AT, anaesthesia trainee; AN, anaesthesia nurse. *Remaining categories are ‘coordination via work environment’, ‘meta-coordination’, and ‘other communication’. They were, however, not included in the current data analysis

	Phase I: routine			Phase II: critical event		
	AT	AN	Total	AT	AN	Total
Task management	10.39	6.87	17.26	10.42↑	3.07↓	13.49↓
Information management	2.81	4.10	6.91	8.78↑	10.63↑	19.41↑
Remaining categories*	2.60	6.81	8.41	2.61	2.33	4.94
Overall coordination activities	15.80	17.78	32.58	21.81	16.03	37.84

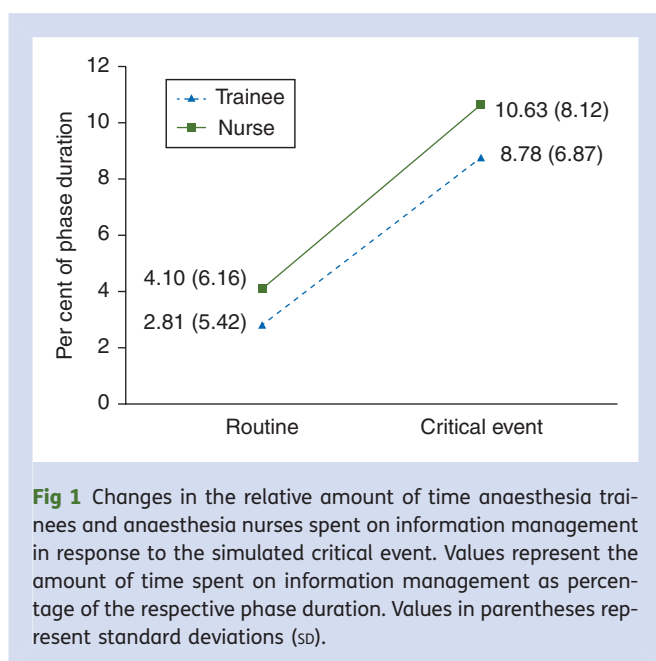


Fig 1 Changes in the relative amount of time anaesthesia trainees and anaesthesia nurses spent on information management in response to the simulated critical event. Values represent the amount of time spent on information management as percentage of the respective phase duration. Values in parentheses represent standard deviations (SD).

Adaptation in coordination activities in relation to the critical event

We hypothesized that the critical event would affect the coordination activities of the anaesthesia teams, particularly regarding team member and type of coordination activities.

Information management

A mixed two-way ANOVA revealed a significant main effect of phase, $F_{1,28}=15.17$, $P=0.001$; anaesthesia teams responded to the asystole by spending more time on information management [$\Delta_{\text{Phase II}-\text{Phase I}}=0.063$, 95% CI (0.096, 0.030)]. In contrast, neither the main effect of team member [$F_{1,28}=0.72$, $P=0.40$; $\Delta_{\text{Trainee}-\text{Nurse}}=-0.016$, 95% CI (-0.054, 0.022)], nor the interaction between the phase and team member was significant ($F_{1,28}=0.03$, $P=0.86$), indicating that trainees and nurses adapted their information management in a similar way. Figure 1 illustrates the changes in information management for both team members.

Task management

With task management as the dependent variable, the ANOVA yielded a different result. There was neither a main effect of phase $F_{1,28}=0.54$, $P=0.47$; $\Delta_{\text{Phase II}-\text{Phase I}}=0.026$, 95% CI (-0.035, 0.074) nor of team member $F_{1,28}=3.93$, $P=0.06$. Results do, however, indicate a trend that anaesthesia trainees spent, on average, more time on task management than nurses [$\Delta_{\text{Trainee}-\text{Nurse}}=0.055$, 95% CI (-0.002, 0.11)]. The interaction between the phase and team member was not significant ($F_{1,28}=0.58$, $P=0.45$).

Adaptation and clinical performance

We used two different markers of clinical performance—decision latency and execution latency. They were

uncorrelated, $r=0.018$, P (two-tailed)=0.95, 95% CI (-0.50, 0.52), indicating that each measure represents a unique aspect of performance.

We were primarily interested in whether the adaptations in coordination activities, in response to the critical event, were related to the performance of the anaesthesia teams. Consequently, we calculated the differences between Phases I and II for both types of coordination activities. We correlated these differences (i.e. indicators of the degree of adaptation) with both performance measures. Since we were also interested in whether trainees' and nurses' coordination activities would differ with regard to the relationship to performance, we calculated separate correlation coefficients for both team members.

There was a negative correlation [$r=-0.49$, P (one-tailed)=0.03, 95% CI (0.03, -0.80)] between decision latency and the anaesthesia trainees' change in information management. This indicates that the more the trainee increased his/her information management (e.g. situation assessment, discussing options) after the occurrence of the critical event, the faster the team came to a decision regarding treatment. Neither the anaesthesia nurse's change in information management activities nor either changes in task management were related to decision latency.

The changes in information management and task management were not related to execution latency; the way anaesthesia trainees and nurses adapted their coordination activities did not affect how long it took them to re-establish sinus rhythm.

Discussion

The current study provides evidence for adaptive coordination in response to a simulated asystole during laryngoscopy and the relationship between adaptation and markers of clinical performance. Our findings are in line with a recent research highlighting the importance of information sharing for clinical performance in medical teams, particularly in terms of time sensitivity. For example, the accuracy of decision-making in intensive care teams has been shown to improve if team members engage in more explicit reasoning (i.e. thinking out loud) and talking to the room (i.e. undirected yet clearly understandable assessments of the situation).²⁶ Similarly, in surgery, patients' odds of experiencing complications increased if teams performed less information sharing during operations and subsequent hand-offs.²⁷

Regarding time sensitivity, Manser and colleagues¹² recently found that information management—but only within the first 5 min after a simulated malignant hyperthermia—predicted the clinical performance of anaesthesia teams, with higher performing teams exhibiting more information-sharing behaviours. Similarly, in intensive care, the likelihood of error in information transmission increased with the age of the information.¹⁷

The current study also stresses the importance of which team member engages in information management. In

general, team coordination in healthcare has been found to vary as a function of team member roles.^{19 20} However, no relationship between the behaviour of specific team members or professions and teamwork outcomes has been established. This study shows that only the increase in trainees' information management was related to the teams' clinical performance. This indicates that not only the act of coordination itself but also the *actor* is relevant to clinical performance. Differences in perceived expertise may be the reason for this finding: if information is transmitted by a physician, it may have been considered more significant by the team. Although this result has to be interpreted within the scope of the limitations of our study, we believe it provides initial evidence that successful information management—and team coordination in general—should be investigated with regard to both its timing and team member roles. Moreover, as information management comprises specific behaviours, it could arguably be improved by training.

In terms of task management, we could neither identify differences between the two phases nor relate task management to any of the two performance measures. In the context of previous research, these findings hint at the potentially moderating role of the type of incident. Although the current work failed to establish a statistically significant relationship between task management and performance, a recent study in a similar setting found higher performing anaesthesia teams exhibiting more task management in response to non-routine events.¹⁶ The earlier study featured various types of events; in contrast, the current study focused on a specific critical event. Bradycardia during laryngoscopy is not uncommon and is often rectified without specific treatment. The rare event of severe bradycardia may resemble asystole; it may be difficult to distinguish between the two, and so, an immediate response according to the standardized life support protocols (ACLS) is mandated.^{28 29} In this case, the task is standardized.²¹ In anaesthesia, the relationship of other team processes such as leadership with performance has been found to be influenced by the level of standardization; in standardized situations, routine can substitute leadership behaviour.³⁰ In addition, the importance of situational factors such as occurrence of critical events, standardization, and task-load has been shown repeatedly.^{13–15} Therefore, it is possible that standardization diminished the influence of task management in the current study. In summary, type of event appears to be a likely moderator of the relationship between coordination activities and performance.

With regard to team performance, our study points to the multidimensionality of effective anaesthesia team coordination. Information management correlated with decision latency but not with execution latency. Owing to the protocol for treating an asystole during laryngoscopy, one important critical process was identifying the event as such. As soon as the team decided what to do, the protocol determined the further process which possibly explains why coordination activities, particularly task management, were not related to execution time.

The current study's weaknesses refer to two main challenges in applied research. First, using teams of professionals as unit of analysis has led to a limited sample size and the associated reduced statistical power. This is particularly problematic since we based part of our conclusion on negative findings (i.e. the absence of a relationship between task management and clinical performance). Furthermore, although we tried to control for this factor by using difference scores for coordination rather than absolute values, we did not explicitly address the issue of common work experience. Team members who had worked together before are likely to coordinate differently from teams cooperating for the first time. However, in view of the complexity of teamwork in applied settings, it is difficult to control for, and isolate, the effects of single factors. This work highlights the significance of certain processes (i.e. adaptive coordination); however, further studies (possibly involving larger sample sizes) on the relationship between patient safety and team coordination are required.

Future studies should scrutinize the type of medical incident as a moderator of the coordination–performance relationship, mainly regarding task management. It would be particularly interesting to compare incidents with a standardized response to incidents for which no standard protocol exists. Furthermore, the role of common work experience for effective coordination in medical teams should be investigated. Finally, although the difference in task management between trainees and nurses was not statistically significant, our findings indicate a trend towards trainees exhibiting more task management, especially during the critical event. Future studies should elaborate on role-specific differences in adaptive coordination.

The importance of effective coordination for maintaining safe patient care has been acknowledged in various healthcare settings.² Team coordination is dynamic; the optimal way to coordinate as a team in a given situation depends on a variety of factors. As a result, research in coordination has to control for the 'who' (team member), 'when' (timing), and 'what' (type of coordination). Therefore, recommendations regarding how teams should coordinate their actions are contingent upon the situation. Our findings also suggest that there are more general characteristics of effective team coordination. Successful information management seems to depend on the right timing, that is, there are windows of opportunity for this type of coordination. Furthermore, a team's ability to adapt its coordination activities is crucial to effective performance. As in previous studies, higher performing teams were better able to shift from routine to critical situations—they adapted more effectively.^{2 11 16} Hence, adaptability represents one of the most important skills and should be further scrutinized.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

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Conflict of interest

None declared.

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